Optimizing the role of pulses in crop rotation: biological nitrogen fixation

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Introduction:

The Pulse Research Network is a national research network aimed at optimizing the benefits of pulses in rotation. The network is funded through Agriculture Agrifood Canada (AAFC) through the Agriculture Bioproducts Initiative program (ABIP). A group of scientists in the Department of Soil Science at the University of Saskatchewan and Agriculture Agrifood Canada – Saskatoon are involved in the "*Cropping Systems Module"*. Research streams in this module are focused on maximizing 1) the N-benefits, 2) the environmental benefits (i.e., carbon benefits), and 3) identifying best management strategies to optimize the beneficial role of pulses in crop rotations. While the role of biological nitrogen fixation (BNF) in supplying N to the pulse is generally well understood, the benefit of the pulse to the subsequent crops in rotation is less clear. A particular focus of the research is to quantify root N and rhizosphere N contributions to the soil N pools. The general approach taken in the research is to label plants with stable isotopes (^{15}N and ^{13}C) and quantify contributions to soil N and C fractions. A key component to maximizing the role of pulses in rotations is to determine how often a pulse should be included to achieve maximum benefit. As a part of this objective, a study was initiated to determine if frequency of inclusion affected BNF in the pulse year of the rotation. Results from this study are reported here.

Methods:

Long-term plots at AAFC Scott, SK provided an opportunity to examine pea frequency in rotation on BNF. The AAFC trial is in its 14th year of rotation. Each phase of the rotations are grown each year. Four rotations were selected to investigate, a continuous pea (p-p-p-p), a pea-wheat-pea-wheat (p-w-p-w), a pea-canola-wheat (p-c-w) and a pea-wheat-canola-wheat (p-w-c-w) rotation. Only the pea phase of the rotation was investigated in two years of the rotations (2008 and 2009). Biological nitrogen fixation was quantified using the enriched 15N-isotope dilution technique. A microplot of wheat was hand seeded into each pea plot, after removing the pea plants from the microplot area. A small amount of ^{15}N-labelled NH_4NO_3 was applied to the wheat microplot and an adjacent equal sized microplot of the pea. Because the wheat does not fix N, it takes up all of its N from the soil and enriched fertilizer source. In contrast, the pea takes up some N from the soil and enriched fertilizer, but also acquires some of its N from BNF. The ^{15}N signal in the air for fixation is much lower than the combined soil and fertilizer source, so that the pea tissue ultimately is depleted or diluted in ^{15}N compared to the wheat reference tissue. The amount of dilution is related to the amount of BNF. At harvest,

shoot materials from the pea and wheat microplots were hand harvested, oven dried and ground and analysed for ^{15}N:^{14}N content. In addition, yields and total N in the tissues were determined.

Results and Discussion:

Altering the frequency of pea in rotation affected the amount of BNF (Figure 1). In 2008, pea in the most diverse rotation (p-w-c-w) acquired the most N through BNF and in 2009 pea in the second most diverse rotation (p-c-w) acquired the most N through BNF. The enhancement in the amounts of N fixed by pea in these rotations was 65 kg N ha^{-1} in 2008 and 37 kg N ha^{-1} in 2009. Continuously cropped pea fixed very little N compared to the other rotations. When the percentage of total N from fixation was determined, the same pattern emerged (Figure 2). In 2008 more of the total N in the pea was acquired from BNF in the p-w-c-w rotation and in 2009 more of the total N in the pea was acquired from BNF in the p-c-w rotation. Only 15% of the total N was acquired from BNF in the p-p-p rotation in both years. Initally it was thought that the p-p-p fixed little N through BNF because this rotation would inherently be more susceptible to diseases resulting in an overall unhealthy crop. Continuously cropping pea is not a rotation commonly grown (if ever) but was included in the study as a means of comparison. However, when yields were examined the continuously cropped pea did not yield lower than pea in the other rotations (Figure 3). Harvest indices in both years for all rotations were comparable and in the range expected for dry-land pea. It appears that the more diverse rotations promote better BNF. Alternatively the enhancement of BNF might be specific to the inclusion of canola in rotation.

It is unknown why BNF is inhibited in the continuous pea. Although diseases affecting yield did not appear to be a problem it may be that microorganisms pathogenic to rhizobia might be enhanced in this rotation. Spring soil available N levels were not different under the different rotations (data not shown), so were not responsible for differentially inhibiting BNF in this rotation. It is unknown whether all pulses behave in the same manner or if the effect observed is specific to pea.

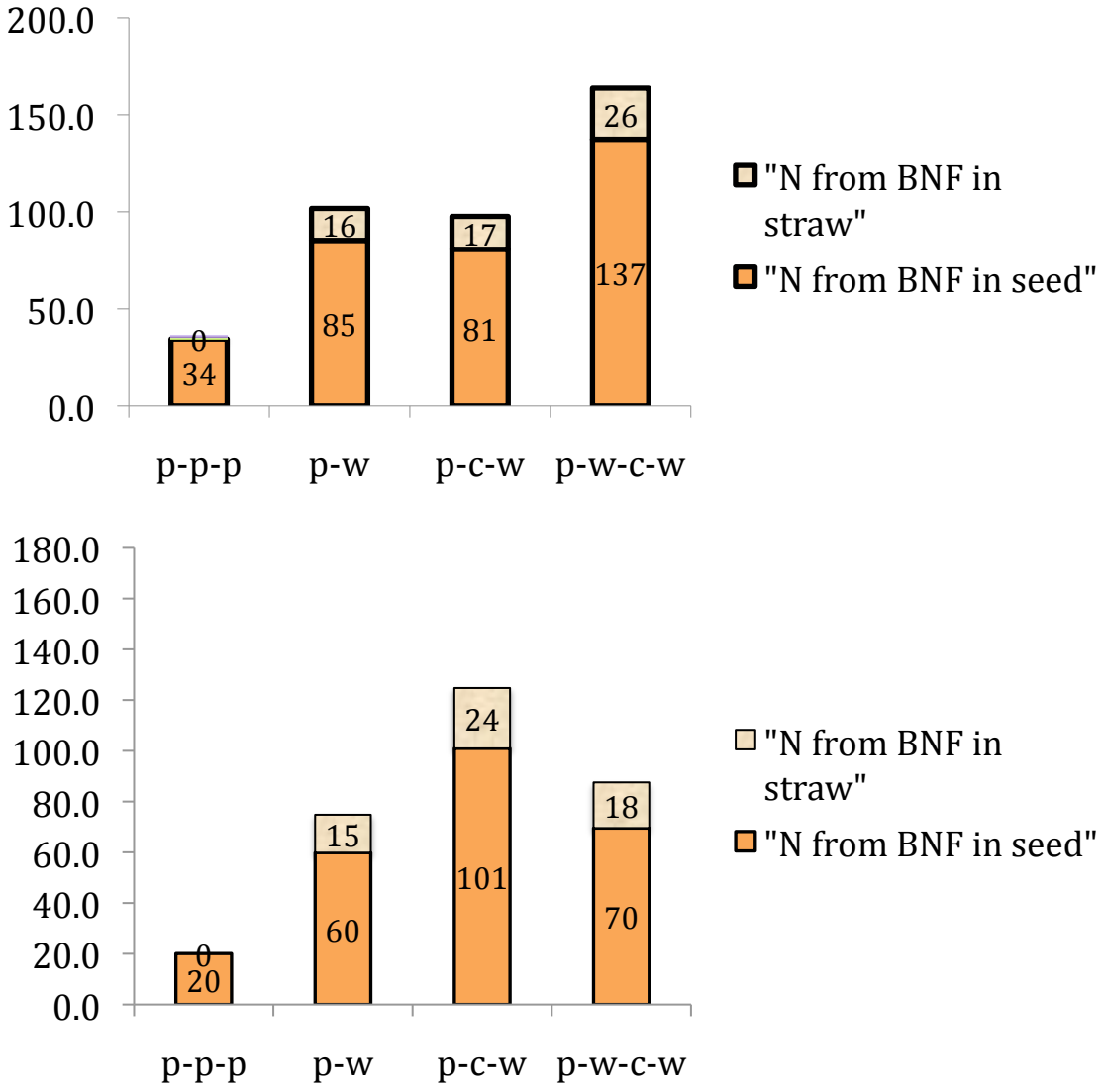

Figure 1. Amount of N acquired (kg N ha^{-1}) from biological nitrogen fixation by pea included in different frequencies in rotations as Scott, SK. Top graph is 2008 data, bottom graph is 2009.

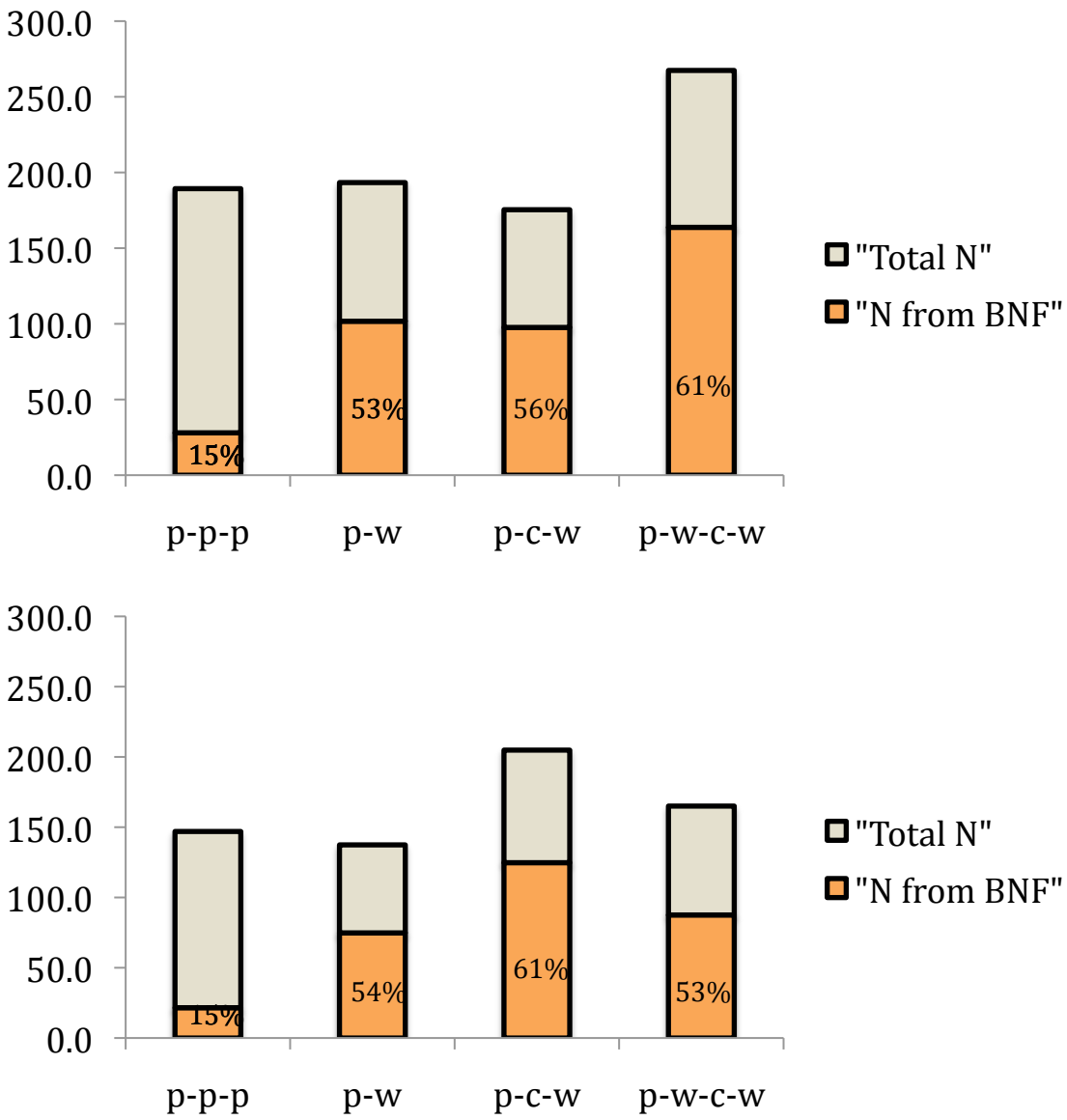

Figure 2. Amount of total N acquired from biological nitrogen fixation (kg N ha^{-1}) by pea included in different frequencies in rotations as Scott, SK. Numbers on bars are the percentage of N from fixation. Top graph is 2008 data, bottom graph is 2009.

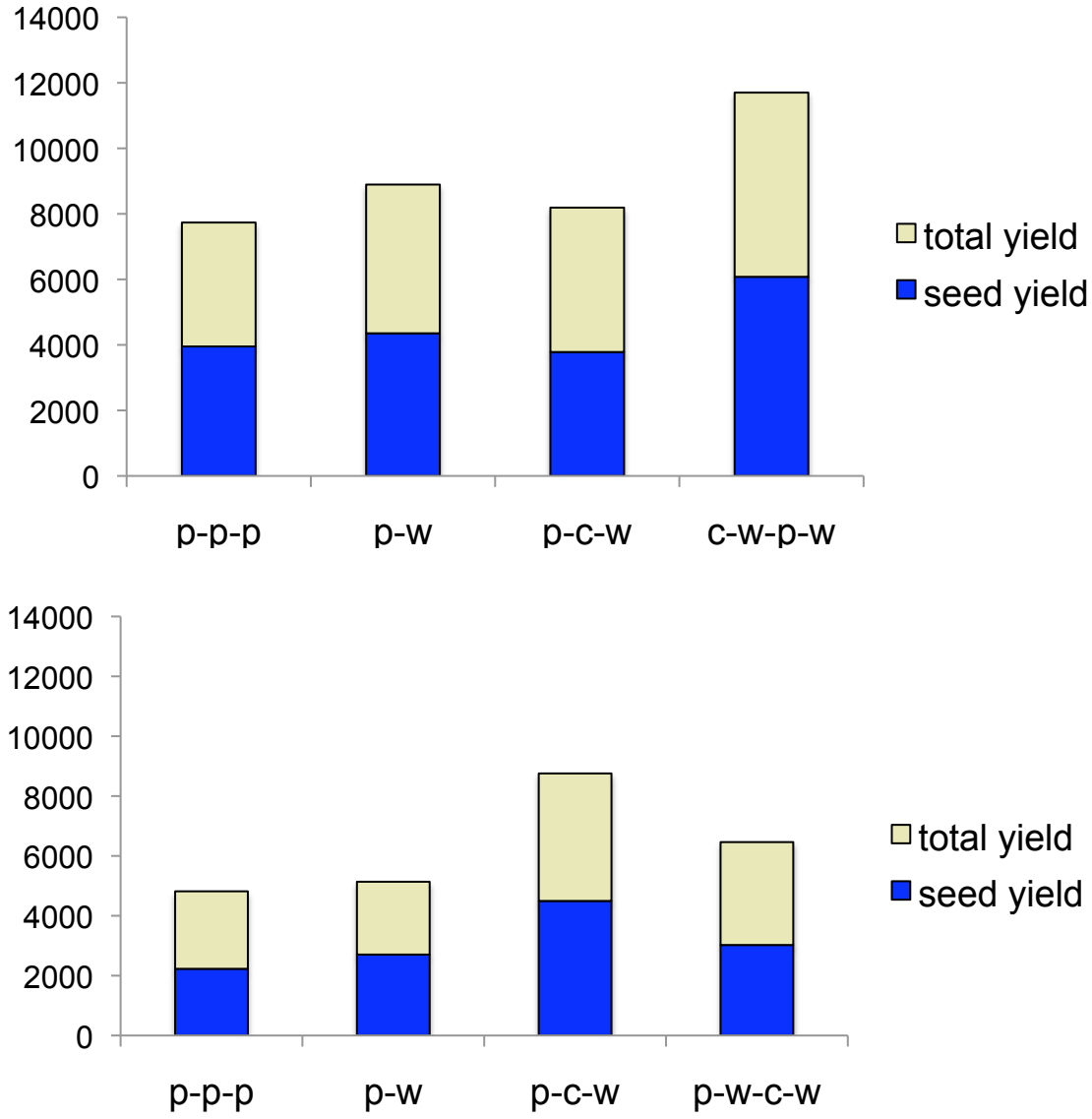

Figure 3. Yields of pea (kg ha^{-1}) included in different frequencies in rotations at Scott, SK. Top graph is 2008 data, bottom graph is 2009.

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